HYDROLOGY DATABASE STORAGE FOR THE DORSET RESEARCH CENTRE

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HYDROLOGY DATABASE STORAGE FOR THE DORSET RESEARCH CENTRE

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1. INTRODUCTION

1.1 Scope of Database

The Limnology Section of the Ontario Ministry of Environment and Energy, through the Dorset Research Centre (DRC), has been monitoring the surface hydrology of a series of small catchments in the Muskoka-Haliburton area since 1976 (Hutchinson et al. 1993a, Scheider et al. 1983). This document describes the architecture of the database used to store the long term hydrologic monitoring data collected by the Dorset Research Centre. This database is of primary importance to the research performed by the DRC and its external collaborators. Continuous, uninterrupted long term databases are becoming increasingly valuable as a record of trends which may be indicative of climate change (Hutchinson 1993).

A major purpose of this study has been the development of catchment water balances for use in hydrochemical mass balances. These mass balances have been vital in assessing the effect of airborne anthropogenic contaminants, such as acid rain and mercury, on the health of soft water ecosystems. Precipitation chemistry is monitored for the study area (Reid and Dillon 1993, Locke and deGrosbois 1986) and provides the atmospheric deposition component. Stream flow is by far the most important contributor to these catchments' water balances. The Limnology Section maintains a network of thirty-four gauged streams within the catchments of eight head water lakes. These streams have been sampled regularly for chemical analysis (Locke and Scott 1986, Girard and Reid 1990). This network provides data on stream flow and other hydrologic parameters which allow the accurate assessments of sub-catchment chemical fluxes.

The lake catchment water balance is an expression of the principle of conservation of mass. It assumes that the sum of water inputs to a catchment are equal to the sum of the outputs.

$$\sum I_G + \sum I_U + P_{LA} + G_I = E + O \pm \Delta L + G_O \tag{1}$$

The inputs terms are: the sum of inflows from the gauged area of the watershed (ΣI_G), the sum of inputs from the ungauged area (ΣI_U), the precipitation falling on the lake surface (P_{LA}) and the groundwater seepage into the catchment (G_I). The loss terms are: the outflow (O), the change in lake level (ΔL), loss from the lake by evaporation (E) and groundwater loss from the catchment (G_O). Note that the change in lake level is entered as a loss, but can be either positive or negative, depending upon whether water is added or removed over the time period for which the balance is performed. It is assumed that the total volume of ground water passing through catchments on the shield is negligible.

Equation 1 can be rearranged to provide an estimate of the accuracy of the measured water balance for a catchment. This balance term is expressed as a percentage. Balances $\pm 10\%$ are considered acceptable by the Limnology Section.

$$B = \frac{(O + E + \Delta L + G_O) - (\Sigma I_G + \Sigma I_U + P_{LA} + G_I)}{O + E + \Delta L + G_O} \times 100\% \tag{2}$$

The methods used to measure the components of the water balance have been described in Scheider et al. 1983 and more recently in Hutchinson et al. 1993b.

An extensive suite of programmes have been developed for calculation of mean daily stream discharge (Futter et al. 1993). Figure 1 shows these major programmes, and the tables they require or populate.

The SPOTQ programme converts stream flow readings to discharge estimates. The stage-discharge estimate pairs are stored in the H_SPOTQ table. Equations relating stage

to discharge have been generated by a number of programmes, including SQOPT6. The equation parameters are stored in the H_OPTIMIZE table. Stage at each structure is logged to a strip chart on a Leupold-Stevens recorder (Scott 1993). These strip charts are digitized using CHART and SETUP. The stage data are then run through the STREAM program, where a look-up table (H_SDT) containing interpolations of the equation relating stage to discharge is used to produce mean daily discharge data. Since the mean daily discharge data is sometimes incomplete due to equipment failure, missing flows are filled in with the ESTIMATE programme. Results of the estimations are stored to H_FLOW_EST and H_FLOW_EQN. The final, complete stream hydrology data is stored in H_FLOW. All of these programmes are described in more detail in Scott et al. (1993).

1.2 Definitions

This report uses the following definitions for some standard hydrologic terms:

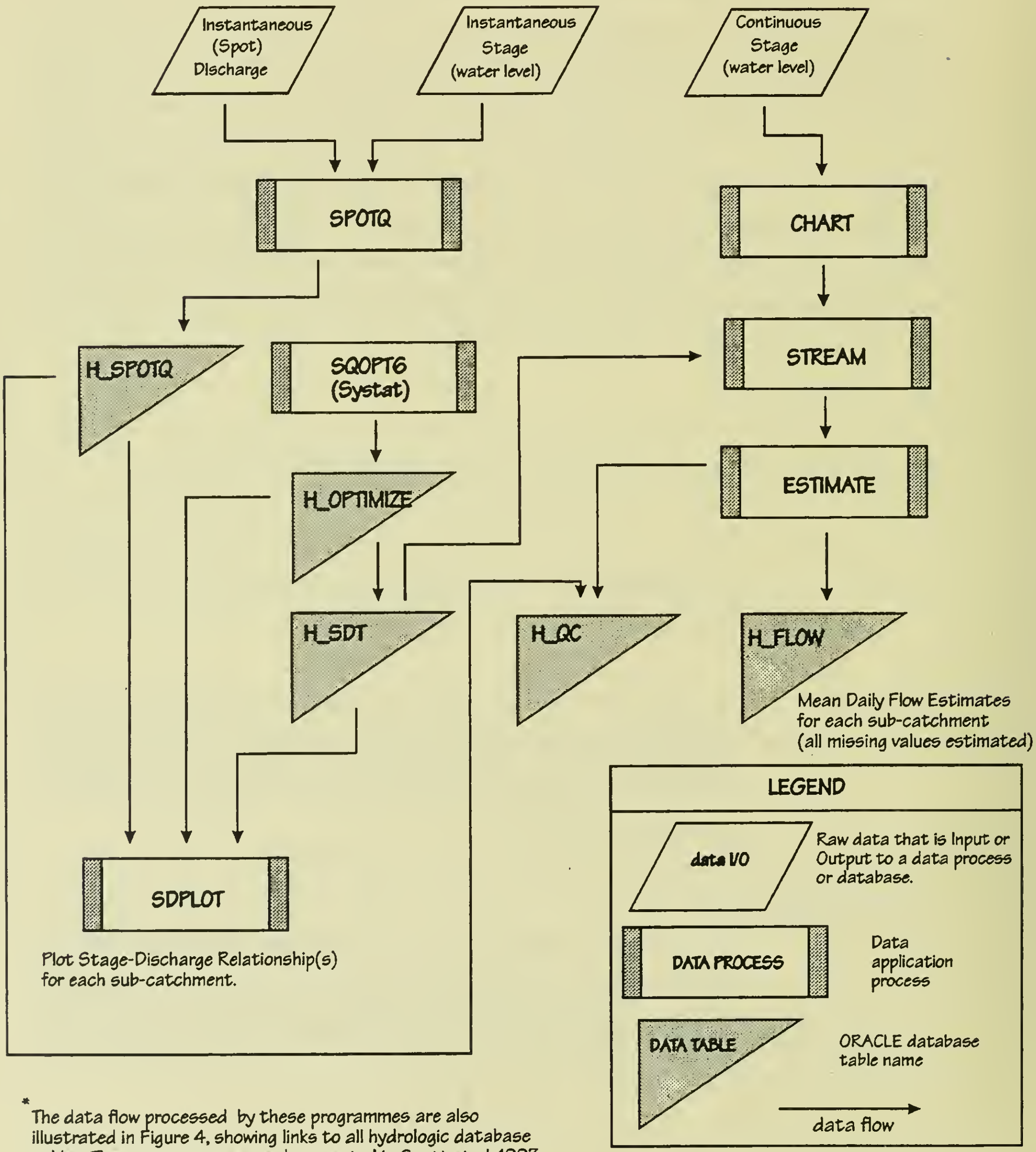
Hydrologic Year — The hydrologic year is a twelve month period from June 1 to May 31. The hydrologic year from June 1, 1980 to May 31, 1981 is identified as 1980.

Mass Balance — A mass balance is the product of a chemical concentration (units $/m^3$) multiplied by a volume of media (m^3), which in this case is water, multiplied by a time step. Mass balances are expressed as amounts of chemical per unit time.

Catchment Water Balance

The catchment water balance is the difference between the inputs to and losses from the catchment of water. This figure can be expressed as a percentage by dividing the balance by the sum of losses (see Eqn. 2):

Figure 1. Programmes* Used in Generating Stream Flow Estimates by the Dorset Research Centre.



* The data flow processed by these programmes are also illustrated in Figure 4, showing links to all hydrologic database tables. These programmes are documented in Scott et al, 1993.

Figure 2 illustrates some of the geographic entities which are required in the generation of stream hydrology and catchment water balances. These entities are defined as follows:

Watershed	The watershed is the outer boundary around a catchment. It is the point of elevation where flow breaks. All points inside the boundary drain into the catchment, while no points outside the watershed drain into the catchment. The watershed extends around the line of break in flow, and the structure on the outflow stream of the catchment.
Catchment	The catchment is the total area within a watershed boundary.
Sub-Watershed	Within a watershed, there can be numerous sub-watersheds. A sub-watershed is the boundary around a sub-catchment which drains into a single input stream.
Sub-Catchment	The sub-catchment is the area drained by a single input to a lake.
Gauged Sub-Catchment	A gauged sub-catchment measures all inputs from the area within its sub-watershed. This is accomplished with a structure which is used to monitor flow of water out of the sub-catchment.
Ungauged Sub-Catchment	Portions of some lake catchments are ungauged due to geomorphological considerations. Ungauged sub-catchments may have only ephemeral stream flow. Flow from ungauged sub-catchments is usually estimated by pro-rating the flow from the appropriate gauged sub-catchments to the area of the ungauged sub-catchment.

Stream — A stream follows the contours of the lowest points in the catchment. A stream is the path of water flow out of a sub-catchment.

Figure 3 illustrates the components of two generalized weirs. The definitions for each component are as follows:

Gauging Structure — The gauging structure is a cut-off wall spanning the stream channel. It is designed according to hydrologic conventions (Reinhart and Pierce 1964, Russell 1937, Parshall 1926) for the measurement of all surface flow at a point as close to the lake as possible.

Staff Gauge — The staff gauge marks the stage in the pool of water behind the gauging structure. All other reference heights (stages and notch points) refer to the height (in metres) above the bottom of the staff gauge.

Stage — The stage is the height of water measured above an established level at a gauging structure.

Notch Point — A notch point is the stage where a change in geometry of the weir or flume in a gauging structure occurs (see Figure 3). The notch point is reported as a height above the bottom of the staff gauge.

Notch — The notch is the range of stages for which a stage discharge relationship is valid. From Figure 3, it can be seen that a notch is the range of heights between two notch points.

Zero Head — Zero head is the minimum stage above the bottom of the staff gauge at which flow through the structure can occur. Zero head is the lowest notch point.

Figure 2. Illustration of the hydrologic terms used to describe a watershed (eg. Harp Lake watershed shown).

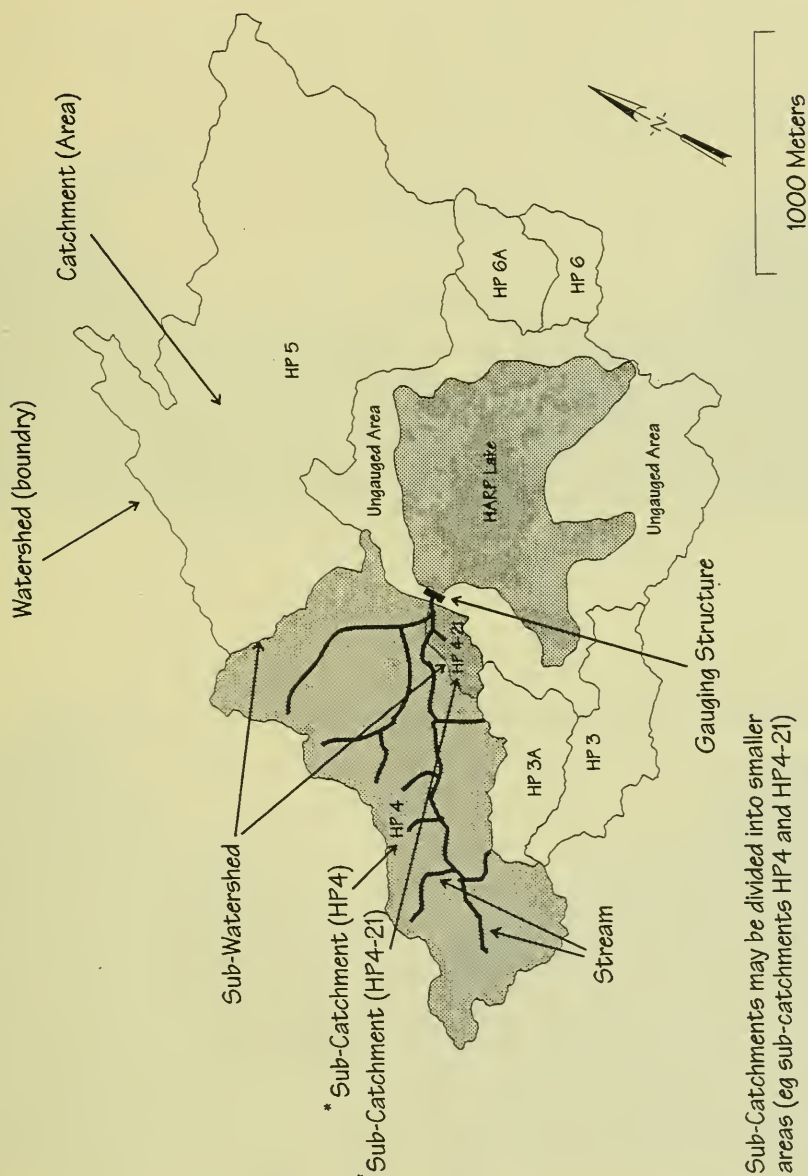
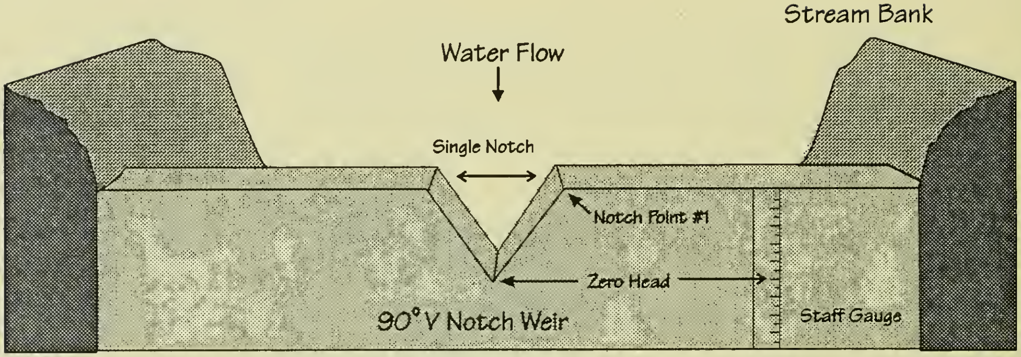


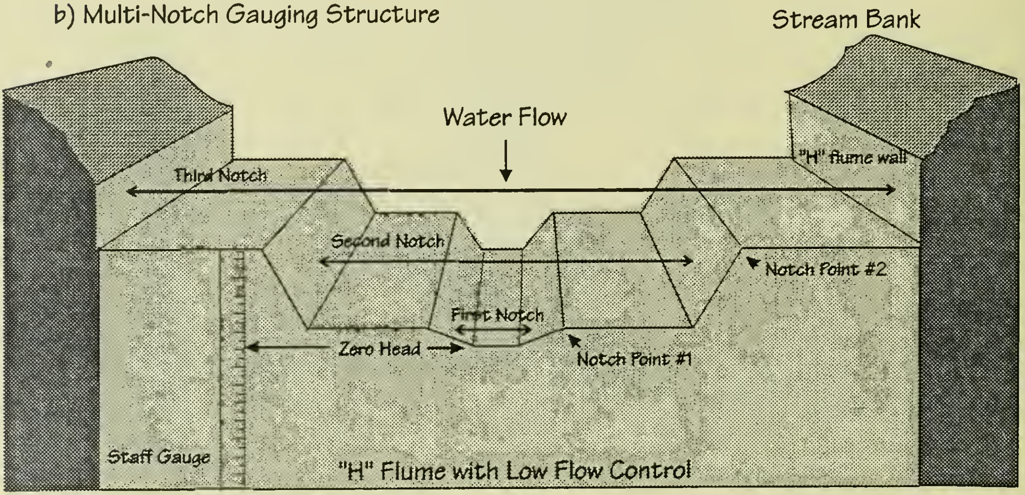
Figure 3. Design of 2 typical gauging structures,
a) 90° V-notch weir and b) multi-notch flume.

a) Single 90° V-Notch weir



Stream Gauging Structure (downstream side)

b) Multi-Notch Gauging Structure



Stream Gauging Structure (downstream side)

2. THE HYDROLOGY DATABASE

The Limnology Section has developed a large number of relational databases for the management of environmental data sets. Databases have been set up for water chemistry (LaZerte et al. 1990), an acid sensitivity survey, regional meteorology (Futter et al. 1993), catchment biogeochemistry and environmental mercury. Biological databases have been developed for phytoplankton, zooplankton (Pawson and Yan 1992), crayfish, benthic invertebrates, aquatic insects and contaminants in sport fish. These databases have been developed in such a way as to provide links to external databases, including the MISA databases, and the SIS data repository. Data from any of the databases maintained by the Dorset Research Centre can be seamlessly combined. Figure 4 illustrates some of these links. Links to the meterological database (M_DAILY) are required to obtain precipitation, relative humidity, radiation and temperature data for calculating evaporation and water balances. Links to the water chemistry database (WATER) allow for the calculation of catchment chemical loadings.

2.1 Database Design

The tables in the Limnology Section hydrology database can be divided into three classes, depending on the type of data they contain. These classes are: data, support, and catchment water balance tables. Figure 5 shows the master-detail relationship within the hydrology tables and the links to the two other major site database tables (WATER and M_DAILY). Data tables contain measured or estimated data on stream flow (H_FLOW), instantaneous stage-discharge observations (H_SPOTQ), lake levels (H_LAKE_LEVEL), and lake evaporation (H_EVAP).

Support tables contain the intermediate results generated in the estimation of hydrologic parameters and ancillary reference data required to describe the database. H_AREAS contains information on catchment area. Monitoring site location data is stored in H_STATION. H_SDT contains look-up tables for the STREAMS programme, and the

equations used to relate instantaneous discharge to stage are stored in H_OPTIMIZE. The support tables also contain quality control information; explanations of quality control codes (H_QC), and data on the gauging structures (H_GAUGING_STRUCT, H_GAUGING_STRUCT_TYPE). H_BALANCE_GROUP contains the stream names for use in balancing the water budget of a catchment. H_FLOW_EQN is used to store the equation parameters used to fill in missing flow data, and H_FLOW_EST contains the estimates of missing flows.

Catchment water balance tables store the inflow data contributing to a catchment water balance (H_WAT_BAL_INLET), and the complete catchment balance data (H_WAT_BAL). Hydrochemical mass balance tables (ST_LOAD, PREC_LOAD and LAKE_BAL_LOAD) are described in detail in Hutchinson et al. 1993b.

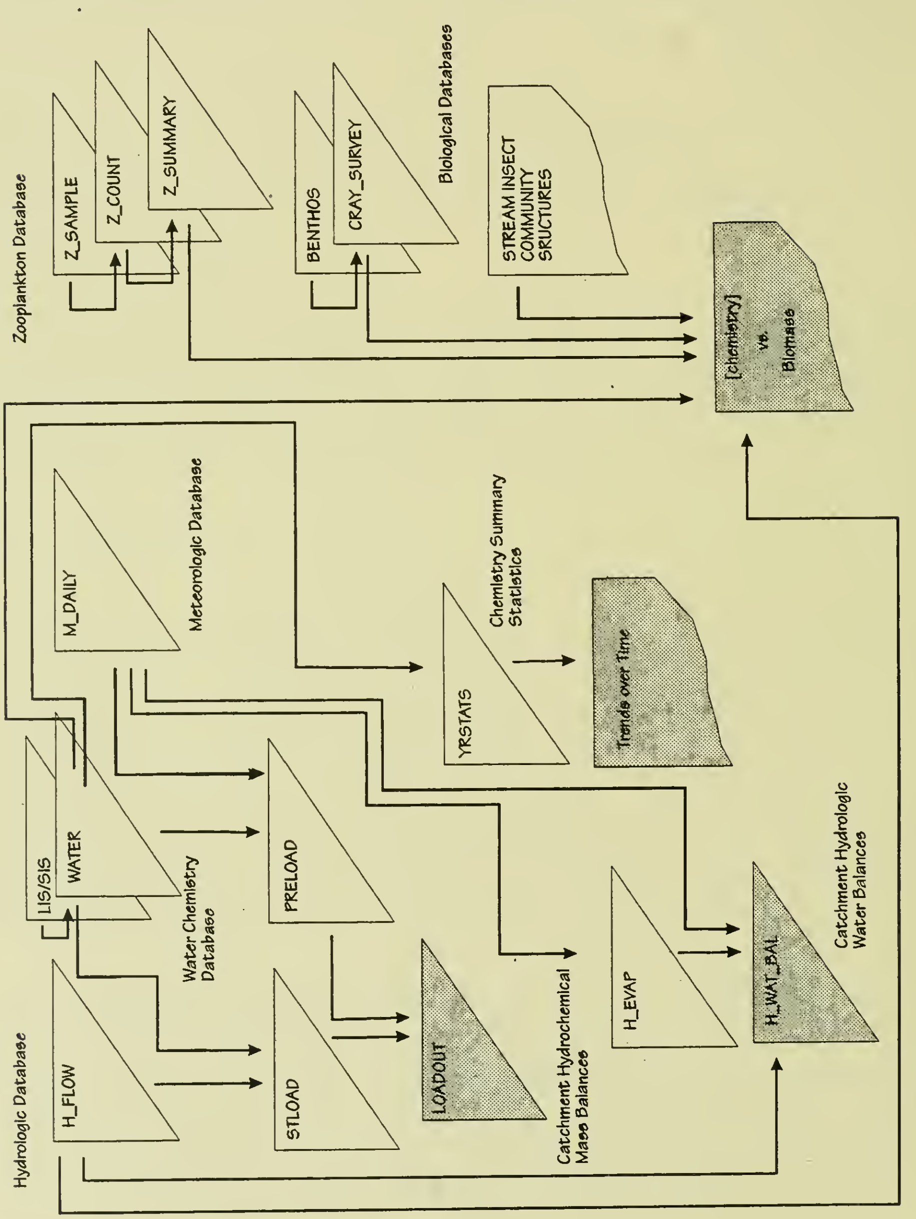
2.2 Database Access

All of the hydrologic data collected by the DRC are stored in a relational database management system, or RDBMS (Date 1983, 1990). The DRC uses the ORACLE RDBMS supporting a subset of ANSI Level 2 SQL. Table design and labelling conventions conform to standards set by the DRC for all ORACLE databases managed by the Limnology Section of the Water Resources Branch (LaZerte et al. 1990, Pawson, Yan 1993, Hutchinson et al. 1993b). Currently, the database resides on an HP-9000 mini computer system running HP-UX. The database is directly accessible from UNIX terminals, as well as remotely through DOS and OS/2 work-stations attached to the DRC thin ethernet LAN.

The hydrologic database may be queried using any one of the standard access methods. These include SQL*Plus, ORACLE for 1*2*3 or Q (LaZerte et al. 1990). The database may be accessed across the LAN directly through SQL*TCP/IP (Oracle 1990a) or through an OS/2 gateway using SQL*NMP (Oracle 1990b). . Many DRC developed application programmes also retrieve data from the database using either Statit, a statistical package running on the Limnology Section mini-computer, or embedded SQL.

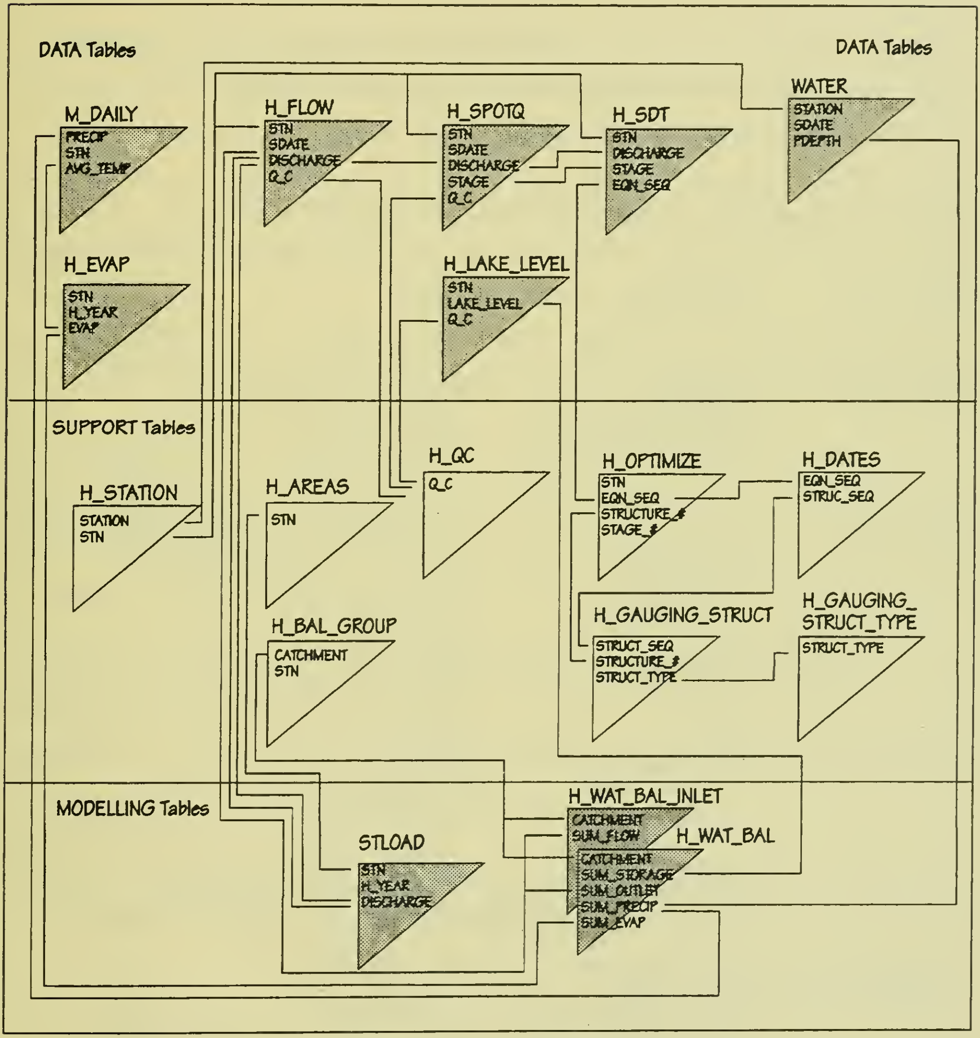
Procedures for updating and transfer of hydrologic data to the database are documented in Scott et al. 1993.

Figure 4. Links between some of the DRC databases.



Note: Shaded areas represent presentation of output data results.

Figure 5. Master-Detail relationship of the hydrology database tables* and their links to the meteorologic and water chemistry databases.



* Column names shown are those that link the hydrology database to other DRC tables. Section 3 of this document describes each of the hydrology tables completely.

3. TABLE STRUCTURES

Table 1 lists all the hydrology database tables along with a brief description. This section describes the purpose of each table in the hydrologic database. The columns are listed and a definition provided for each column. Columns identified by an asterisk (*) are the unique primary key for each record. Alternate primary keys are indicated with an "A" following the column data type. Foreign keys are identified with an "F".

Table 1 Hydrology database tables at the Dorset Research Centre

Table Type	Table Name	Purpose
Data Tables:	H_SPOTQ	Instantaneous "Spot" discharge data
	H_FLOW	Daily mean discharge data
	H_LAKE_LEVEL	Lake level data
	H_EVAP	Lake evaporation estimates
Support Tables:	H_BALANCE_GROUP	Station parameters used for calculating water balances for a catchment
	H_AREAS	Catchment, lake and sub-catchment areas
	H_STATION	Station location information
	H_OPTIMIZE	Optimized equations to predict discharge from stage
	H_DATES	Dates calibration equations are valid
	H_SDT	Look up table for the STREAMS programme containing stage-discharge pairs
	H_FLOW_EST	Temporary table containing estimates of missing flow values
	H_FLOW_EQN	Equation parameters used for filling in missing flow data
	H_QC	Quality control flags and their descriptions
	H_GAUGING_STRUCT	Catchment gauging structures
	H_GAUGING_STRUCT_TYPE	Gauging structure descriptions
Catchment Water Balance Tables:		
	H_WAT_BAL	Water balances
	H_WAT_BAL_INLET	Inlet supply terms to water balance

3.1 Data Tables

H_SPOTQ Table

This table contains instantaneous discharge measurements taken for each structure. Structures were monitored historically for instantaneous discharge and stage on a weekly basis. For most structures, the stage-discharge relationship is well defined at low and medium flow ranges. Stage height is monitored weekly at each site. Instantaneous discharges are only measured at periods of high flows, during periods of abnormal flow, and when the structure is being recalibrated.

	COLUMN	DATA TYPE		
*	STN	CHAR(7)	NOT NULL	F
*	SDATE	DATE	NOT NULL	
	STAGE	NUMBER		
	DISCHARGE	NUMBER		
	DISCHARGE_	NUMBER		F

STN A unique station identifier for each monitored stream.

SDATE The date the discharge was measured. This value is stored in ORACLE date format.

STAGE An instantaneous measurement (in metres) for a height of water in the structure. The value is read from three staff gauges, located at the structure. Only one of the values is entered to the database (the other measurements are kept as a backup reference during subsequent data work-up).

DISCHARGE

A discharge rate (in L/sec) is taken for each recorded stage. Discharge measurement values are derived as described in Scott et al. (1993) and Locke and Scott (1986).

DISCHARGE_

This column contains a warning flag generated by the SPOTQ programme (Scott et al. 1993). Usually, it indicates that pre-determined current velocity recorder cross sectional radii have been incorrectly applied.

H_FLOW Table

This table contains mean daily discharge records, in L/sec, for all monitored streams. These records are derived from chart records (Locke and Scott 1986, Scott et al. 1993) and converted to mean daily discharge using Automated Stream Flow Computation Programme (Water Survey of Canada, 1977). A complete description of the methods to compute these data, as well as the missing value estimations over the period 1976 to present are described in Scott et al. 1993.

	COLUMN	DATA TYPE		
*	STN	CHAR(7)	NOT NULL	F
*	SDATE	DATE	NOT NULL	
	DISCHARGE	NUMBER		
	DISCHARGE_	NUMBER		F

STN A unique station identifier for each monitored stream.

SDATE A continuous daily date vector (i.e., there are no missing dates from the beginning of operation for a gauging structure).

DISCHARGE An estimate of mean daily discharge for STN at SDATE (in L/sec).

DISCHARGE_ A numeric quality control flag is associated with every discharge value. A full description of the meaning of the flag can be found in the H_QC table.

H_LAKE_LEVEL Table

This table contains lake level information for all eight study watersheds. Each lake has more than one staff gauge established due to the high incidence of gauge shifts. The column GAUGE_IN_USE denotes the current lake level gauge used. These gauges are related to a permanently established bench mark and levels are corrected to reflect changes in the initial gauge elevation. A complete description of the process of calculating change in lake level is described in Scott (1993).

	COLUMN	DATA TYPE		
*	STN	CHAR(7)	NOT NULL	F
*	SDATE	DATE	NOT NULL	
	LAKE_LEVEL	NUMBER		
	LAKE_LEVEL_	NUMBER		F

STN A unique station identification code for each monitoring site. The gauges are installed in the lake and referenced by the STN code of the closest stream.

SDATE The sample date that the lake level data was measured.

LAKE_LEVEL A gauge height reading (in metres) corresponding to the lake level.

LAKE_LEVEL_ Each data value has a quality control flag associated with it. This column can be cross-referenced to the equivalent value in the Q_C column of the H_QC table. The meaning of the flag is listed in the REMARK column of H_QC.

H_EVAP Table

This table contains summaries of depth of water evaporated (in mm/m^2/day) from lake surfaces. A number of methods have been used to estimate evaporation. These methods are fully described in Scheider et al. (1983) and Scott et al. (1993). Data from this table is used as part of the water balance computed for each study catchment for each hydrologic year.

	COLUMN	DATA TYPE		
*	STN	CHAR(7)	NOT NULL	F
*	START_DATE	DATE	NOT NULL	
*	END_DATE	DATE	NOT NULL	
*	EVAP_	NUMBER	NOT NULL	
	H_YEAR	NUMBER	NOT NULL	
	EVAP	NUMBER	NOT NULL	

STN A unique station identifier for each study catchment.

H_YEAR The hydrologic year is a twelve month period running from June 1 to May 31, of the following year (e.g., the hydrologic year from June 1 1980 to May 31 1981 is identified as 1980).

START_DATE The start date of the evaporative period.

END_DATE The end date of the evaporative period.

EVAP The estimate of evaporation from the lake surface (in mm of water/m^2 lake surface).

EVAP_ EVAP_ is a key to the H_QC table. The REMARK in H_QC defines the method used to estimate evaporation at STN between START_DATE and END_DATE.

3.2 Support Tables

H_BALANCE_GROUP

The H_BALANCE_GROUP table lists the sub-catchments and streams used in determining the water balance of a given catchment.

	COLUMN	DATA TYPE	
*	CATCHMENT	CHAR(7)	NOT NULL
	STN	CHAR(7)	NOT NULL

CATCHMENT A unique station identifier for each catchment for which a water balance is calculated.

STN A unique station identifier for each study sub-catchment.

H_AREAS Table

This table contains the areas of each monitored station, the date the survey was performed to determine the area, and whether or not the value is currently in use.

	COLUMN	DATA TYPE		
*	STN	CHAR(7)	NOT NULL	F
*	AREA_IN_USE	CHAR(1)	NOT NULL	
	AREA	NUMBER	NOT NULL	
	SURVEY_DATE	DATE		
	REMARK	CHAR(45)		

STN A unique station identifier for each monitored site.

AREA_IN_USE A flag field denoting whether or not the survey value (AREA) is currently being used in water balance calculations ("Y" = in use, "N" = not in use).

AREA The area of the site in hectares.

SURVEY_DATE The date on which the survey was performed to determine the area of the monitoring site.

REMARK A descriptor field containing any notes on the update of the area value or the method used to derive the value.

H_STATION Table

This table contains geographic information about the monitored hydrologic sites. It also provides a key to the WATER and W_STATION tables.

	COLUMN	DATA TYPE		
*	STN	CHAR(7)	NOT NULL	F
	STATION	CHAR(11)	NOT NULL	F
	WATERSHED	CHAR(6)		
	INFO	CHAR(40)		
	PROJECT	CHAR(4)		
	LATITUDE	NUMBER		
	LONGITUDE	NUMBER		
	ZONE	NUMBER		
	EASTING	NUMBER		
	NORTHING	NUMBER		
	ELEVATION	NUMBER		

STN This is a unique station identifier for each stream sampling site.

STATION This is an external key to the WATER table (LaZerte et al. 1990). It is a unique II digit station identification number (stored as a character).

WATERSHED The tertiary watershed in which a sample collection site is located.

INFO This column contains additional information about the collection site. Often, INFO is the body of water at which the site is located.

PROJECT	This is the MOEE project code associated with STATION (LaZerte et al. 1990).
LATITUDE	The latitude of the site.
LONGITUDE	The longitude of the site.
ZONE	The Universal Transverse Mercator (UTM) Zone in which the site is located.
NORTHING	The UTM northing coordinate.
EASTING	The UTM Easting coordinate.
ELEVATION	The height above sea level (m) at the station.

H_OPTIMIZE Table

This table contains the stage-discharge relationship equations computed for each structure. The derivation of these equations is described in Scott et al. (1993).

	COLUMN	DATA TYPE			
*	EQN_SEQ	NUMBER	NOT NULL		
*	EQN_IN_USE	CHAR(1)	NOT NULL		A
	STN	CHAR(7)	NOT NULL	F	A
	STRUCTURE_#	NUMBER	NOT NULL	F	A
	NOTCH_#	NUMBER	NOT NULL		A
	A	NUMBER			
	P	NUMBER			
	METHOD_	NUMBER			A

EQN_SEQ This is a unique sequence created by the ORACLE database (ORACLE 1991). EQN_SEQ uniquely identifies each STN, STRUCTURE_# and STAGE combination. This column is used primarily to link to the H_DATES table to retrieve the start and end dates (START_CAL and END_CAL) defining a stage-discharge relationship.

EQN_IN_USE This column can be "N" or "Y", depending upon whether a stage-discharge relationship is currently in use. Only one stage-discharge relationship can be in use for a structure at any one time.

STN A unique station identification for each sample collection site.

STRUCTURE_# This is a numeric code unique to a particular structure. In the event that a structure is rebuilt or replaced, a new STRUCTURE_# is assigned to identify the new structure.

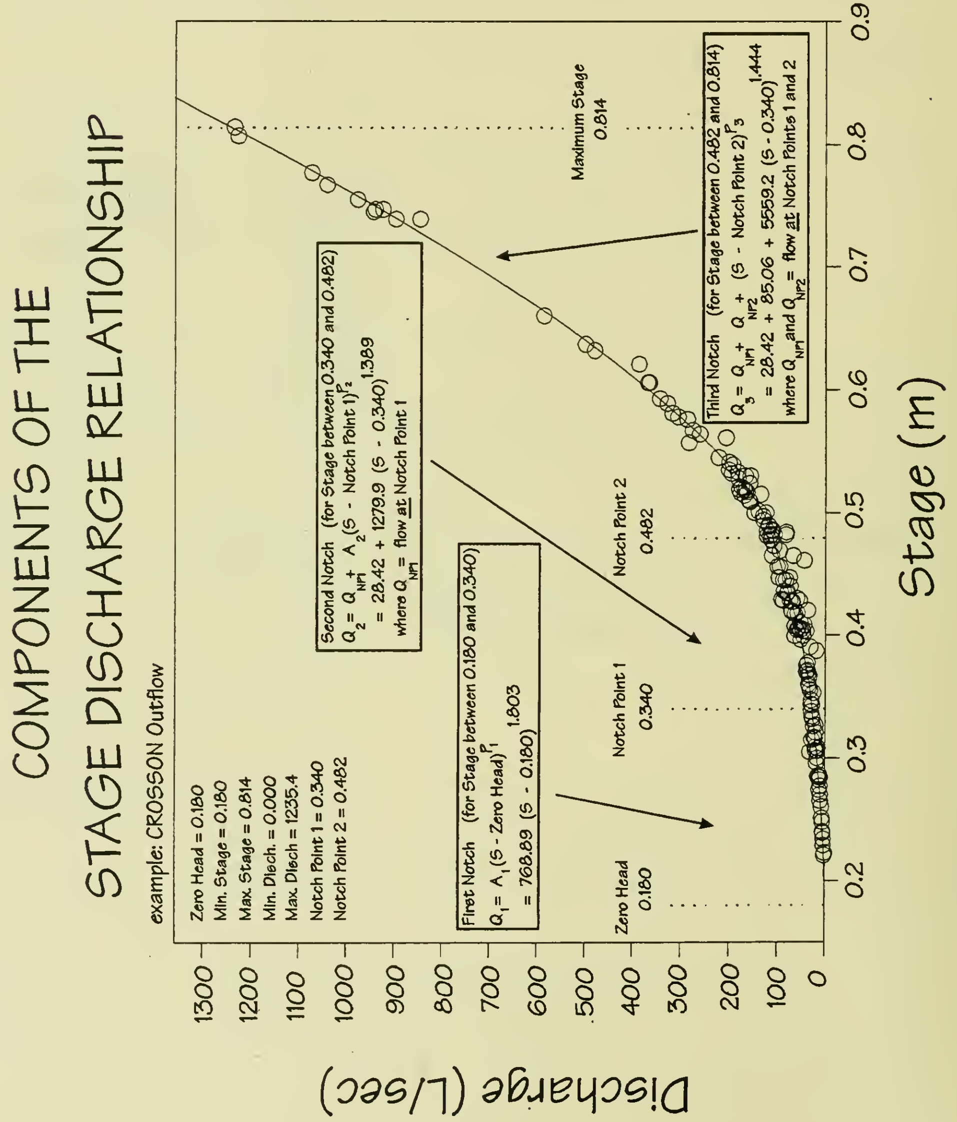
NOTCH_# This is the notch number (see Fig. 3) for which an equation is valid.

A The value of the constant term "A" in the stage(Q)-discharge(S) equation $Q=AS^P$ (Scott et al. 1993). Each notch number has a corresponding "A" term. Figure 6 illustrates the sequential summation of terms of the expression for a structure with more than one notch.

P The value of the exponent term "P" in the stage(Q):discharge(S) equation $Q=AS^P$ (Scott et al. 1993). Each notch number has a corresponding "P" term. Figure 6 illustrates the sequential summation of terms of the expression for a structure with more than one notch.

METHOD_ This is a numeric flag referencing a REMARK in the H_QC table. METHOD_ refers to the programme used to calculate the stage-discharge relationship.

Figure 6. Plot of stage-discharge relationship for a multi-notch gauging structure (with equations for each notch), illustrating the sequential summation of the terms in the expressions.



H_DATES Table

This table contains the date range for which stage-discharge equations are valid, and the date range over which calibration data were collected for producing the equations.

	COLUMN	DATA TYPE		
*	EQN_SEQ	NUMBER	NOT NULL	
*	STRUCTURE_SEQ	NUMBER	NOT NULL	
	STN	CHAR(7)	NOT NULL	F
	START_CAL	DATE		
	END_CAL	DATE		
	START_USE	DATE		
	END_USE	DATE		

EQN_SEQ This is a unique sequence created by the ORACLE database. EQN_SEQ uniquely identifies each STN, STRUCTURE_# and STAGE combination. This column is used to provide a link to both the H_OPTIMIZE and H_SDT tables for the retrieval of start and end dates (START_CAL and END_CAL) defining a particular stage-discharge relationship.

STRUCTURE_SEQ This is a unique sequence generated by the ORACLE database. There is a unique STRUCTURE_SEQ code for every structure ever built by the Limnology Section. STRUCTURE_SEQ uniquely identifies a STN, STRUCTURE_# combination.

STN A unique station identification for each sample collection site.

START_CAL The date on which the collection was started of stage discharge pairs for use in producing a stage-discharge relationship for a given STN and

STRUCTURE_#. This date may define a new structure (STRUCTURE_#), or a different relationship calculated for this structure due to changes in survey data.

END_CAL The date on which collection of stage-discharge pairs for use in deriving a stage-discharge relationship for STRUCTURE_# at STN was completed.

START_USE The first date for which the stage-discharge relationship for STRUCTURE_# at STN is valid, and in use for predicting flow.

END_USE The last date for which the stage-discharge relationship for STRUCTURE_# at STN was valid.

H_SDT Table

The H_SDT table contains interpolated stage-discharge data pairs generated from the equations stored in H_OPTIMIZE. These data are required to translate stages to mean daily flows (Scott et al. 1993). Exactly fifty (50) stage-discharge pairs are required by hydrology data work-up programmes for each STN, STRUCTURE_# combination (Scott et al. 1993).

	COLUMN	DATA TYPE		
*	EQN_SEQ	NUMBER	NOT NULL	
	STN	CHAR(7)	NOT NULL	F
	STAGE	NUMBER		
	DISCHARGE	NUMBER		

EQN_SEQ This is a unique sequence created by the ORACLE database. EQN_SEQ uniquely identifies each STN, STRUCTURE_# and STAGE combination. This column is used primarily to link to the H_DATES table to retrieve the start and end dates (START-CAL and END_CAL) defining a stage-discharge relationship, and to link to the H_OPTIMIZE table to retrieve the A and P coefficients of that relationship.

STN A unique station identifier for each stream sample site.

STAGE The interpolated stage (in metres).

DISCHARGE The interpolated discharge (in L/sec).

H_FLOW_EST Table

This table is used to store estimated flow values when missing hydrology data are being filled in (Scott et al. 1993). This table is intended to be used primarily for temporary storage of iterative flow estimations. Generally, only the H_FLOW table should be used after missing flow data have been appended to it.

	COLUMN	DATA TYPE	
*	STN	CHAR(7)	NOT NULL
*	SDATE	DATE	NOT NULL
*	STATUS	CHAR(1)	
	DISCHARGE	NUMBER	
	DISCHARGE_	NUMBER	

STN A unique station identifier for each monitored stream.

SDATE The date for which flow was estimated at STN.

STATUS A flag identifying whether or not an estimate is interim (I), or final (F).

DISCHARGE An estimate of mean daily discharge (in L/sec) generated according to the procedures in Scott et al. (1993).

DISCHARGE_ A numeric quality control flag is associated with every value. A full character descriptor field can be referenced from the H_QC Table under the Q_C and REMARK columns.

H_FLOW_EQN Table

This table contains the equation parameters used in filling in missing hydrology data as a function of flow in other streams (Scott et al. 1993). This table serves primarily as a reference.

	COLUMN	DATA TYPE	
*	STN	CHAR(7)	NOT NULL
*	START_DATE	DATE	NOT NULL
*	END_DATE	DATE	NOT NULL
*	STATUS	CHAR(1)	
	INTERCEPT	NUMBER	NOT NULL
	STREAM	CHAR(7)	
	MULT	NUMBER	

STN A unique station identifying the stream for which flow is being predicted.

START_DATE The first date in the period for which missing flows for STN were to be estimated.

END_DATE The last date for which missing flows for STN were to be estimated.

STATUS A flag identifying whether or not an estimate is interim (I), or final (F).

INTERCEPT The intercept in the multiple regression equation predicting missing stream flow for STN between START_DATE and END_DATE.

STREAM A unique station identifier for the stream used to predict flow.

MULT The factor by which FLOW at STREAM is multiplied to substitute into the multiple regression equation predicting DISCHARGE at STN.

H_QC Table

This table contains the quality control numeric flag values and the corresponding description of the remark associated with them. There are several flags used to document daily discharge data, particularly historic data (pre 1984), and there are also several flags output with optimized hydrograph values and estimation of missing data procedures. Table 2 contains a list of all flags currently in the table with a description of each.

	COLUMN	DATA TYPE	
*	Q_C	NUMBER	NOT NULL
	REMARK	CHAR(60)	NOT NULL

Q_C — A numeric quality control flag (many were originally derived from the ASCII ordinate of the first letter of the REMARK).

REMARK — A full description of the Q_C flag containing valid date ranges, and comments about the validity of the data value.

Table 2 Quality control flags and remarks used to describe the hydrologic database.

Q_C flag	**REMARK on use of flag**	
67	Real Value (from strip chart)	(76-present)
69	Visually Estimated Flow	(76-80)
72	Hydrographed with Real Values	(76-present)
73	Ice in the gauging structure	(80-84)
77	Missing	
78	No flow to estimate	(84-present)
81	Spot Q used to estimate flow	(76-present)
82	Regression used to estimate flow	(76-84)
83	Stage height used to estimate	(76-present)
86	Visual estimate of zero flow	(76-present)
88	Extrapolated from PC1	(76-present)
104	Hydrographed with estimated values	
115	Stepwise regression	(84-present)
122	Forced to zero	(84-present)
200	Station not calibrated	
300	Spot discharge clear and okay	(84-present)
301	Upstream obstruction data integrity not affected	(84-present)
302	Downstream obstruction data integrity affected	(84-present)
303	Obstruction in control	(84-present)
304	Stage observed only, discharge predicted from H_OPTIMIZE	(84-present)
305	Recorder integrity suspect	(84-present)
1000	Estimated with SQOPT6	(84-89)
1001	Estimated with SYSTAT Nonlin Module	(89-present)
2000	Estimated evaporation with EVAPOR8	(80-89)
2001	Estimated evaporation with MORTON model	(89-present)
2002	Interpolated from MORTON model	(89-present)

H_GAUGING_STRUCT Table

This table contains the structure survey information used in the optimization of the stage discharge relationship (found in H_OPTIMIZE). The data includes a zero head value for every structure, as well as any other valid notch points as part of the stream gauging structure. Figure 3 illustrates the stage discharge relationship and differentiates the notch and notch point.

	COLUMN	DATA TYPE		
*	STRUCTURE_SEQ	NUMBER	NOT NULL	P
	STN	CHAR(7)	NOT NULL	A
	STRUCTURE_#	NUMBER	NOT NULL	A
	STRUCT_IN_USE	CHAR(1)		A
	STRUCT_TYPE	NUMBER		F
	NUM_NOTCHES	NUMBER		
	ZEROHEAD	NUMBER		
	NOTCH_PT1	NUMBER		
	NOTCH_PT2	NUMBER		
	WIDTH	NUMBER		

STRUCTURE_SEQ This is a unique sequence generated by the ORACLE database. There is a unique STRUCTURE_SEQ code for every structure ever built by the Limnology Section. STRUCTURE_SEQ uniquely identifies a STN, STRUCTURE_# combination. This column is used primarily to link to the H_DATES table to retrieve the start and end dates (START_USE and END_USE) defining the use of a structure.

STN A unique station identifier for each monitored stream.

STRUCTURE_# This is a numeric code unique to a particular structure. STRUCTURE_# is created as a sequence in the ORACLE database.

Many sub-catchments have had only one structure, but several have had new structures constructed or alterations to the original.

STRUCT_TYPE The STRUCT_TYPE field is a key to an extended description of the structure contained in the H_GAUGING_STRUCT_TYPE table.

STRUCT_IN_USE A flag field denoting whether or not the structure identified by STRUCTURE_SEQ is currently being used ("Y" = in use, "N" = not in use).

NUM_NOTCHES The number of notches in a weir or structure. This ranges from one to three for DRC gauging structures (see Figure 6).

ZEROHEAD This value represents the height of water where flow no longer crests the lowest point of the structure (see Figure 3).

MAXHEAD This stage represents the maximum projected height attained at the structure. It does not represent the maximum stage at which an instantaneous discharge was measured, nor the point at which loss of control at the structure is reached.

NOTCH_PT1 This is the stage (in metres) of a first notch point above the zero head for a structure. This point will define the upper boundary of a first notch. NOTE: NOTCH_PT1 will only contain values for structures with NUM_NOTCHES $\pm$ 2 (see Figure 6).

NOTCH_PT2 This is the stage (in metres) of a second notch point for a structure. NOTE: NOTCH_PT2 will only contain values for structures with NUM_NOTCHES $\pm$ 3 (see Figure 6).

H_GAUGING_STRUCT_TYPE Table

This table contains additional information on the types of gauging structures used on all gauged catchments. This table can be referenced to H_GAUGING_STRUCT which contains the numeric codes for these structures types.

	COLUMN	DATA TYPE		
*	STRUCT_TYPE	NUMBER	NOT NULL	F
	DESCRIPTOR	CHAR(65)	NOT NULL	

STRUCT_TYPE A single numeric code corresponding to a gauging structure type (this key cross references to the H_GAUGING_STRUCT table).

DESCRIPTOR Additional description of the structure type.

3.3 Catchment Water Balance Tables

H_WAT_BAL Table

This table contains the terms of Equation 1 (described in Section 1.1), defining the water balance for each catchment of a watershed by hydrologic year. The supply terms for the water balance are the volume of precipitation falling on the lake surface (SUM_PRECIP), flows from gauged inlets (SUM_INLET) and the total contribution from ungauged sub-catchments (SUM_UNGAUGED). The loss terms are the total outflow (SUM_OUTLET), total evaporation (SUM_EVAP) and change in storage (SUM_STORAGE). This table is keyed, by CATCHMENT and H_YEAR, to the H_WAT_BAL_INLETS table which contains the INLET supply terms of the hydrologic water balance. The percentage water balance and yearly estimates of real runoff and water yield are computed from data in this table. Figure 5 illustrates where the supply and loss terms are stored in the database.

	COLUMN	DATA TYPE		
*	CATCHMENT	CHAR(7)	NOT NULL	F
*	H_YEAR	NUMBER	NOT NULL	
	SUM_PRECIP	NUMBER		
	SUM_UNGAUGED	NUMBER		
	SUM_OUTLET	NUMBER		
	SUM_EVAP	NUMBER		
	SUM_STORAGE	NUMBER		

CATCHMENT A unique station identifier for each catchment for which a water balance is calculated.

H_YEAR The hydrologic year for which the water balance was calculated.

SUM_PRECIP The volume of precipitation added to the lake surface (10^3m^3) over the course of a hydrologic year. This value is the sum of monthly precipitation values multiplied by the lake area.

SUM_UNGAUGED Total discharge (in 10^3m^3) from the ungauged portion of the watershed to the lake over the course of a hydrologic year.

SUM_OUTLET Total discharge (10^3m^3) from the catchment outlet over the course of a hydrologic year. This is a loss term in the water balance.

SUM_EVAP Total volume of water evaporated from a lake surface over the course of a hydrologic year (10^3m^3). This figure is calculated as the depth of evaporation times the lake surface area.

SUM_STORAGE The net change in lake volume from the start to end of a hydrologic year (10^3m^3). This figure is calculated as the change in height of the lake level between the start and end of the hydrologic year times the surface area of the lake.

H_WAT_BAL_INLET Table

This table contains the inlet supply terms of the water balance for each inflow to a catchment by hydrologic year. Data in this table is keyed to the table H_WAT_BAL on the columns CATCHMENT and H_YEAR.

	COLUMN	DATA TYPE		
*	CATCHMENT	CHAR(7)	NOT NULL	F
*	H_YEAR	NUMBER	NOT NULL	
*	INLET	CHAR(7)	NOT NULL	
	SUM_FLOW	NUMBER		

CATCHMENT A unique station identifier for each catchment for which a water balance is calculated.

H_YEAR The hydrologic year for which the water balance was calculated.

INLET A station identifier for each sub-catchment in the watershed.

SUM_FLOW The sum of the daily inlet flow for the hydrologic year from the sub-catchment into the lake.

3.4 External Tables

There are three external tables routinely used in constructing models with finalized hydrologic data. These are the table of daily meteorologic observations, M_DAILY; the water chemistry, WATER; and the table containing stream loading estimates, ST_LOAD. These tables are completely documented in Futter et al. 1993, LaZerte et al. 1990 and Hutchinson et al. 1993b, respectively.

The M_DAILY table contains daily weather observations from the monitoring networks run by the Limnology Section and Atmospheric Environment Services, Canada. These data are required to determine the precipitation amount in catchment water balance estimates, and as input data for calculating evaporation estimates (Scott et al. 1993).

The WATER table is used to store chemistry data extracted from SIS, the Sample Information System (LaZerte et al. 1990). These data are combined with hydrologic data to perform a series of chemical mass balances (Hutchinson et al. 1993b). The results of the chemical mass balances are stored in the ST_LOAD table.

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Sample queries to plot stage-discharge relationship(s) for a sub-catchment (using the current Stage Discharge Lookup Table (SDT) for the structure).

Query #1

Get the stage and discharge data for the sub-catchment, measured for this structure over a date range for which the current SDT relationship is valid.

```
SQL>
        SELECT STAGE, DISCHARGE
        FROM H_SPOTQ
        WHERE STN = "CN0"
        AND SDATE> =
            (SELECT DISTINCT (START_USE) FROM H_DATES D, H_OPTIMIZE O
            WHERE O.EQN_SEQ = D.EQN_SEQ
            AND O.EQN_IN_USE = "Y" AND O.STN = "CN0")
        AND SDATE< =
            (SELECT DISTINCT (END_USE) FROM H_DATES D, H_OPTIMIZE O
            WHERE O.EQN_SEQ = D.EQN_SEQ
            AND O.EQN_IN_USE = "Y" AND O.STN = "CN0")
        ORDER BY STAGE;
```

Generated output from this example:

SQL>

Stage	Discharge
0.221	1.756
0.223	0.972
0.229	3.101
0.234	3.262
0.239	4.453
. .	
. .	
. .	
. .	
0.807	1227.16
0.814	1235.43

Query #2

Get the SDT currently in use for a gauging structure on this sub-catchment (there may have been both other structures and other SDT's used on this stream).

```
SQL>
    SELECT STAGE, DISCHARGE
    FROM H_SDT S, H_OPTIMIZE O
    WHERE STN = "CN0"
    AND S.EQN_SEQ = O.EQN_SEQ
    AND O.EQN_IN_USE = "Y";
```

Generated output from this example:

SQL>

Stage	Discharge
0.18	0
0.1954	0.414920795
0.2108	1.44784571
0.2262	3.00756363
0.2416	5.05218641
.	.
.	.
.	.
.	.
0.9346	1880.52772
0.95	1968.00876

Query #3

Get the equation(s) that represent this SDT for this sub-catchment.

```
SQL>
    SELECT NOTCH_#, A, P
    FROM H_OPTIMIZE
    WHERE STN = "CN0" AND EQN_IN_USE = "Y"
```

Generated output from this example:

SQL>

Notch #	A	P
1	0.768892	1.803
2	1.279924	1.389
3	5.559189	1.444

Figure 7. Links to H_OPTIMIZE illustrating a sample query to obtain the current stage-discharge relationship curve(s) and equation(s) to apply to the sample measurements of instantaneous (spot) stage and discharge values for a sub-catchment.